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Effect of Compost and Phosphate Applications on the Growth, Cadmium and Lead Uptake by Maize Plants Grown on Contaminated Soils

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ABSTRACT

A pot experiment with maize (single cross-2030) was conducted to study the influence of phosphorus sources and levels and compost additions on growth, cadmium (Cd) and lead (Pb) contents of maize, as well as the availability of cadmium and lead in rhizosphere soil after the harvest of maize plants in three contaminated soils. It was observed in the three soils used in this study that compost addition increased significantly shoots and roots dry weight of maize plants and performed better than phosphate. With the three soils used in the study, results indicated that plants grown in soils amended with compost and supplied with rock phosphate (RP) at the high phosphate level, recorded the highest shoots & roots dry weight. Cadmium & lead contents of the both shoots & roots of maize plants were significantly reduced as a result of compost treatment. Rock phosphate addition significantly reduced Cd and Pb contents of both shoots and roots compared to single supper phosphate (SSP) for all soils examined. Increasing phosphate levels markedly reduced Cd and Pb contents of both shoots and roots with all soils studied. Also, the results revealed that plants grown in soils amended with compost and supplied with RP at high phosphate level recorded the lowest cadmium and lead contents of shoots and roots for the three soils used in this study. The availability of cadmium and lead in rhizosphere area after the harvest of maize plants were significantly decreased in all soils studied as a result of compost treatments. RP treatments significantly decreased the availability Cd and Pb in rhizosphere area of all soils studied compared to SSP addition. The available Cd and Pb in rhizosphere area were reduced as a result of increasing phosphate levels. The lowest value of available cadmium and lead in rhizosphere area of all studied soils were recorded for soils amended with compost and treated with RP at the high phosphate level.

Keywords: contaminated soil, heavy metals, compost and phosphate application

INTRODUCTION

Heavy metals are existent in soil as natural components or as a result of the bad use of human. Heavy metals even at any concentrations can cause toxicity to humans and other forms of life, their pernicious effects on human health are quite (Kumar, *et al*., 2017). Cadmium and lead have dangerous effect due to the high toxicity they pose to the environment and humans (El Razek, 2014). Since metals are not degraded, one strategy applied for modification of contaminated soils with metals is immobilization achieved when one metal is transformed into a more stable geochemical form, which reduces its bioavailability. As an alternative technique, in situ metal immobilization using soil amendments has been promoted as a immediate, cost-effective, and low disruption technique (Keller *et al*., 2005; Lee *et al*., 2009). There are a lot of amendments, such as organic amendments (Beesley *et al*., 2014 ; Karer *et al*., 2015) and phosphate minerals (Guo, *et al*., 2018) have been developed for minimize the availability of heavy metals in soils. These technologies may induce adverse effects on soil health and food safety (Chuan-chuan *et al*., 2016).

The addition of organic amendments, such as compost to polluted soils can make a great variety of processes, leading to improvements in physico-chemical soil properties and fertility status and even altering the heavy metal distribution in the soil (Bernal *et al*., 2007). techniques for enhanced bioremediation of heavy metals such as, cadmium and lead by organic treatments include: immobilization, reduction and rhizosphere modification. Addition of organic amendments to contaminated soils help to reduce the mobility, the phyto-availability and toxicity of pollutants and, at the same time, increase soil fertility, improve soil aeration and water holding capacities; in order to improve plant development (Kidd *et al*., 2009). The use of organic refinements for retrieving heavy metal contaminated soils has been tested by different researchers (Clark *et al*., 2007; Herwijnen *et al*., 2007 ; Gondar and Bernal 2009 ; Liu *et al*., 2009 ; Farrel *et al*., 2010). For the most of these experiments the uptake of heavy metals by plants was reduced by addition of organic materials to the soil.

On the other hand, the inorganic amendments such as, phosphate fertilizers are also effective in heavy metal bio-availability through formation of stable mineral heavy metal phosphate (Liang *et al*., 2012). The possible techniqes for heavy metal stabilization by phosphate minerals include the following: the formation of amorphous or poorly crystalline metal phosphate precipitation; ion-exchange interaction and surface complexation at the surface of rock phosphate and isomorphic substitution of Ca in rock phosphate by other heavy metals during recrystallization or coprecipitation process (Cao *et al*., 2004 ; Saxena and D'Souza 2006). The formation of these insoluble metal compounds (metal-phosphate complexes) through the application of phosphate materials, reduce their mobility through the soil profile, the pool available for biota (Geebelen *et al*., 2003), and considered a major immobilization approach for Pb & Cd contaminated soils (Jiang *et al*., 2012; Mignardi *et al*., 2012). Certain Pb-P, and Cd-P complexes are highly stable, with limited solubility and mobility in soils (Waterlot *et al*., 2011 ; Austruy *et al*., 2014). In addition, the application of amendments simultaneously, could enhance plant growth and biological activity of degraded soil (Madejon *et al*., 2006).

The objective of this study is to compare the effectiveness of compost and different phosphate compounds (Rock Phosphate & Single Super Phosphate) on the growth, cadmium and lead uptake by maize plants grown on contaminated soils.

MATERIALS AND METHODS

A pot experiment was conducted in the greenhouse of Soil Science Department, Faculty of Agriculture, Cairo University, Giza, Egypt to investigate the influence of compost and different phosphate sources on the growth and uptake of cadmium and lead by maize plants in some contaminated soils.

Soil samples

Three soil samples were collected from the surface layer (0 – 30 cm) of heavy metals polluted soils, one from Helwan region, Cairo, Egypt (S1) and the two others from EL-Gabal EL-Asfar, Cairo, Egypt (S2and S3).The Soil Sample were air dried, crushed, sieve through a 2 mm sieve and thoroughly mixed before use. The main properties of the studied soils are given in Table 1.

Table 1. The main physical and chemical properties of the studied soils.

Characteristics	Values Helwan region (S1)	EL-Gabal EL-Asfar S2	 S3
Particle size distribution			
Sand %	49.2	76.3	89.0
Silt %	24.4	12.1	5.4
Clay%	26.4	11.6	5.6
Textural Class	Sandy clay loam	Sandy loam	Sand
pH (1 ; 2.5)	8.12	7.1	6.84
EC (1:5)	0.14	0.22	1.44
Organic matter	4.42	3.09	2.73
Soluble Cations (meql^{-1})			
Ca^{++}	0.6	2.0	5.0
Mg^{++}	0.3	0.8	3.0
K^{+}	0.2	0.1	0.3
Na^{+}	1.0	1.1	6.3
Soluble anions (meql^{-1})			
HCO_3^- and CO_3^{--}	0.8	0.9	2.4
Cl^-	1.0	1.75	6.0
SO_4^{--}	0.3	1.35	6.2
Available N (mgkg^{-1})	6.52	11.29	7.6
Available P (mgkg^{-1})	80.6	76.6	78.6
Available Cd (mgkg^{-1})	0.20	0.37	0.27
Available Pb (mgkg^{-1})	11.43	36.31	43.02

Soil amendments:

The soil amendments used in this study were: a compost (as organic amendment was mad from a mixture of ornamental plants waste), natural rock phosphate (RP) and single supper phosphate (SSP). Main physical and chemical properties of soil amendments are given in Table 2 . Compost was added to the three studied soils at two rates, (0 and 20 ton feddan^{-1}), both RP and SSP were applied to the studied soils (S1, S2 and S3) at three levels 30, 45 and 60 kg P_2O_5 feddan^{-1}

Plant growth experiment:

The pot experiment was conducted on all three soils used in the study. The experiment was performed in 12 treatments and three replicates per treatment for each soil. A basal dose of N and K fertilizer, equivalent to 120 kg N feddan^{-1} as ammonium nitrate (33%N) and 50 kg as K_2O feddan^{-1}was added as potassium sulphate (50% K_2O), respectively and mixed thoroughly with 10 kg air dried soil. The soil samples were then placed in plastic pots of (21 cm in height & 25 cm in diameter). Amendments were also air-dried and ground to pass through a 2 mm mesh sieve, and were then applied as designed and mixed with the soil samples thoroughly. Ten seeds of maize were sown into each pot and then thinned to five seedlings after germination. The plants were watered daily by hand to maintain soil water content at 60% of water holding capacity. Plant samples were collected after 60 days. Plant samples were up rooted as gently as possible without tearing of root system and the shoots were separated.

Table 2. Physical & chemical characters of the amendments used in the experiment.

Compost		Rock Phosphate	
Characteristics	**Value**	**Characteristics**	**Value**
Density (kgm^{-3})	590	Total (P_2O_5%)	24
Humidity(%)	27.0	Total cadmium (mgkg^{-1})	4.0
pH(1:10)	7.6	Total lead (mgkg^{-1})	14.4
EC (1:10) dSm^{-1}	4.04	Single Super Phosphate	
Organic matter (%)	53.99	Characteristics	Value
Organic carbon (%)	31.31	Available (P_2O_5%)	15.5
Ash %	73.0	Total cadmium (mgkg^{-1})	2.53
Total Nitrogen %	1.6	Total lead (mgkg^{-1})	8.5
C / N ratio	15.6 : 1		
Total Phosphrous (%)	0.95		
Total Potasium (%)	1.68		
Total cadmium (mgkg^{-1})	ND		
Total lead (mgkg^{-1})	9.1		

Soil analyses

The available heavy metals (cadmium & lead) were determined according to Lindsay and Norvell, (1978).Total heavy metals (cadmium & lead) were determined according to Cottenie *et al.* (1982).The concentrations of cadmium & lead were determined by Atomic Absorption Spectrophotometer. Mechanical analysis of the three soil samples were performed according to the pipette method Piper (1950). Organic matter by oxidation with dichromate, according to Walkely and Black as described by Jackson (1973). Soil pH was measured in a 1:2.5 soil : water ratio using a glass electrode as described by Jackson (1973). Electrical conductivity (EC) was measured in soil past outlined by Jackson (1973). Available phosphorus was determined by using molybdenum blue method described by El-Hinediy and Agiza (1959). Available nitrogen was determined by the Kjeldahl method Jackson (1973).

Plant analysis

At the end of the experiment, plants were harvested, rinsed with deionized water, separated into shoots and roots, dried at 70 °C for 72 hours in an oven. For determining the Cd and Pb concentration in the plants, dried roots and shoots were grinded. Dry matter of maize (shoots &roots) were digested using mixture of sulfuric and perchloric acids. Jackson (1973).

Statistical analysis:

Test of normality distribution was carried out according to Shapiro and Wilk, method (1965), by using SPSS v. 17.0 (2008) computer package. A randomized complete block design with three factors were used for analysis all data with three replications for each parameter. Estimates of LSD were calculated to test the significance of differences among means according to Snedecor and Cochran (1994). by used Assistat program.

RESULTS AND DISCUSSION

Shoots and roots dry weight of maize plants:

The results presented in Table 3 show the effect of organic and phosphate treatments on shoots & roots dry weight of maize plants. It is clear that in the three soils used in this study (S1, S2 and S3), irrespective of phosphate treatments, compost application significantly increased both shoots and roots dry weight .The magnitude of increase in shoots dry weight resulted from compost application were 19.92, 17.87 and 18.65% for S1, S2 and S3, respectively, compared to without compost application. The corresponding values for roots dry weight were 11.32, 17.08 and 19.16%. These results could be enhanced with those obtained by (Ahmad *et al* ., 2015 and Abo-El-Enein *et al*., 2017), they reported that both root and shoot biomasses of wheat plant increased with the application of organic amendments. Excessive cadmium and lead content in soils have been reported to inhibit the development of root system of plants (Andrei *et al*., 2003) , impede photosynthesis (Krupa and Moniak, 1998) and even lower crop yield (Verma and Dubey, 2001). The application of organic amendment in the present study significantly decreased the bioavailabilty of cadmium & lead, alleviated their toxicity to maize root, support the development of maize root therefore enhanced maize plants growth (Table 3 and 6).

Table 3. Shoots & roots dry weights of maize plants as affected by compost and phosphate fertilizer applications (g. pot^{-1})

			Shoots				Roots			
	C.T.	F.L.	Fertilizer sources (F.S)			C. Mean	Fertilizer sources (F.S.)			C. Mean
			SSP	RP	mean		SSP	RP	mean	
S 1	C_0	L 1	38.21^{e}	34.42^{f}	36.31^{d}	37.299^{b}	10.82^{hi}	10.46^{i}	10.64^{e}	12.613^{b}
		L 2	40.01^{d}	35.47^{f}	37.74^{c}		13.12^{ef}	11.61^{gh}	12.37^{d}	
		L 3	40.65^{d}	35.04^{f}	37.85^{c}		15.27^{bc}	14.4^{cd}	14.84^{b}	
		Mean	39.62^{c}	34.97^{d}			13.07^{b}	12.16^{c}		
	C_1	L 1	42.34^{c}	48.66^{a}	45.50^{b}	46.577^{a}	12.78^{ef}	12.21^{fg}	12.50^{d}	14.223^{a}
		L 2	44.94^{b}	48.72^{a}	46.83^{ab}		13.45^{de}	13.00^{ef}	13.23^{c}	
		L 3	45.86^{b}	48.95^{a}	47.40^{a}		16.21^{b}	17.69^{a}	16.95^{a}	
		Mean	44.38^{b}	48.78^{a}			14.15^{a}	14.30^{a}		
	Mean	F.S.	42.00^{a}	41.88^{a}			13.61^{a}	13.23a		
		F.L.	40.91^{b}	42.28^{a}	42.62^{a}		11.565^{c}	12.793^{b}	15.891^{a}	
S 2	C_0	L 1	42.57^{cd}	40.40^{d}	41.48^{b}	42.021^{b}	13.96^{de}	12.20^{f}	13.08^{e}	14.392^{b}
		L 2	43.24^{cd}	40.94^{d}	42.09^{b}		14.64^{de}	13.89^{e}	14.27^{d}	
		L 3	44.93^{c}	40.05^{d}	42.49^{b}		16.93^{b}	14.73^{d}	15.83^{c}	
		Mean	43.58^{c}	40.46^{d}			15.18^{c}	13.61^{d}		
	C_1	L 1	49.62^{b}	51.23^{ab}	53.43^{a}	51.163^{a}	16.97^{b}	16.97^{b}	16.97^{b}	17.37^{a}
		L 2	50.54^{ab}	52.15^{ab}	54.34^{a}		15.58^{c}	17.50^{b}	16.54^{b}	
		L 3	50.33^{ab}	53.12^{a}	54.73^{a}		17.45^{b}	19.67^{a}	18.56^{a}	
		Mean	50.16^{b}	52.17^{a}			16.67^{b}	18.05^{a}		
	Mean	F.S.	46.87^{a}	46.32^{a}			15.92a	15.83^{a}		
		F.L.	45.95^{a}	46.72^{a}	47.107^{a}		15.025^{b}	15.402^{b}	17.194^{a}	
S 3	C_0	L 1	43.59^{cd}	39.24^{e}	41.42^{b}	42.038^{b}	14.30^{gh}	13.37^{h}	13.84^{f}	15.040^{b}
		L 2	44.27^{c}	40.04^{e}	42.16^{b}		15.50^{ef}	14.50^{fg}	15.00^{e}	
		L 3	44.17^{c}	40.92^{de}	42.54^{b}		16.97^{d}	15.60^{e}	16.29^{c}	
		mean	44.01^{c}	40.07^{d}			15.59^{c}	14.49^{d}		
	C_1	L 1	49.34^{b}	53.88^{a}	52.61^{a}	51.675^{a}	16.83^{d}	18.23^{c}	17.53^{c}	18.605^{a}
		L 2	49.09^{b}	53.65^{a}	52.37^{a}		16.97^{d}	19.73^{b}	18.35^{b}	
		L 3	50.42^{b}	53.67^{a}	53.05^{a}		19.50^{b}	20.35^{a}	19.93^{a}	
		mean	49.62^{b}	53.73^{a}			17.77^{b}	19.44^{a}		
	Mean	F.S.	46.81^{a}	46.90^{a}			16.68^{a}	16.97^{a}		
		F.L.	46.51^{a}	46.76^{a}	47.295^{a}		15.683^{c}	16.675^{b}	18.105^{a}	

C_o = without compost application, C_1= with compost application, SSP= single super phosphate, RP= Rock phosphate, C.T. = Compost treatment, F.L. = Fertilizer level .

At the three soils studied (S1, S2 and S3), regardless of compost treatments, both phosphate sources and levels had no significant effect on shoots dry weight, on the other hand, increasing phosphate levels, significantly increased roots dry weight, while phosphate sources had no significant effect on roots dry weight for S1, S2 and S3 soils. The obtained results are in accordance with the results of Zhu *et al*. (2004) they reported that the application of phosphate sources there is are no significant effect on the shoot biomass of plants, and slightly increased root biomass in some treatments.

In all studied soils (S1, S2 and S3), shoots and roots dry weight of plants grown in soil non-amended with compost and supplied with SSP significantly were greater than those supplied with RP. This is may be due to that, the soluble-P treatment (SSP) has often been shown to immobilize heavy metals effectively in soils than insoluble P sources (RP) (Basta and McGowen 2004 ; Park *et al.* 2011 ; Mignardi *et al*., 2012), so that plants grown in soil non-amended with compost and supplied with SSP recorded the highest shoots and roots dry weight, while insoluble phosphorus sources (RP) in the presence of compost showed the greater shoots and roots dry weight of plants. The potential of RP to immobilize Cd and Pb this probably due to that organic amendments enhanced the bioavailability of RP and there for, enhanced immobilization of heavy metals.

Concerning the interaction between compost treatments and phosphate levels, the data showed that, at each soil studied, increasing phosphate levels significantly increased roots dry weight in both compost treatments. In contrast, shoots dry weight did not affected significantly by the interaction effect of compost and phosphate levels for all soils studies. As regards to the interaction effect of compost, phosphate sources and levels, the data in Table 3 show that , for all soils studied, plants grown in soil amended with compost and supplied with RP at high phosphate level recorded the highest shoots & roots dry weight

Shoots and roots cadmium content of maize plants

Cadmium (Cd) content of shoots and roots were significantly affected by compost, phosphate sources and levels and the interaction effect Table 4. It was noticed that in all soils studied (S1,S2 and S3) regardless of phosphate treatments, Cd content of shoots and roots were significantly decreased as a result of compost application compared to non-application, the percent of decrease in Cd content of shoots were 9 , 36, 27% for S1, S2 and S3, respectively, while the percent of decreased in Cd content of roots were 26.7, 19.1, 13.7 % for S1, S2 and S3, respectively. The obtained results in accordance with the finding of Ahmad *et al* .(2015) they reported that compost significantly reduced Cd uptake in wheat and maize. Angelova *et al.* (2010) reported that organic materials were especially effective for reduction of cadmium content in potato tubers, a correlation was found between the quantity of the mobile forms and the uptake of lead, zinc, copper and cadmium by the potato. Mechanisms for enhanced bioremediation of heavy metals by organic materials include: immobilization, reduction and rhizosphere modification.

Table 4. Shoots & roots cadmium content of maize plants as affected by compost and phosphate fertilizers application (mg kg^{-1}).

			Shoots				Roots			
	C.T.	F.L.	Fertilizer sources (F.S)			C. Mean	Fertilizer sources (F.S.)			C. Mean
			SSP	RP	mean		SSP	RP	mean	
S 1	C0	L 1	0.53^{b}	0.52^{b}	0.525^{a}	0.33^{a}	0.97^{ab}	0.98^{a}	0.97^{a}	0.922^{a}
		L 2	0.24^{e}	0.27^{d}	0.255^{c}		0.91^{bcd}	0.85^{de}	0.88^{b}	
		L 3	0.21^{f}	0.20^{f}	0.205^{d}		0.93^{abc}	0.89^{cd}	0.91^{b}	
		Mean	0.33^{b}	0.33^{b}			0.94^{a}	0.91^{a}		
	C1	L 1	0.60^{a}	0.28^{d}	0.44^{b}	0.30^{b}	0.7767^{f}	0.770^{f}	0.77^{c}	0.676^{b}
		L 2	0.37^{c}	0.17^{g}	0.27^{c}		0.82^{ef}	0.557^{gh}	0.69^{d}	
		L 3	0.29^{d}	0.10^{h}	0.195^{d}		0.61^{g}	0.523^{h}	0.57^{e}	
		Mean	0.42^{a}	0.18^{c}			0.736^{b}	0.616^{c}		
	Mean	F.S.	0.37^{a}	0.26^{b}			0.84^{a}	0.76^{b}		
		F.L.	0.483^{a}	0.263^{b}	0.200^{c}		0.87^{a}	0.79^{b}	0.74^{c}	
S 2	C0	L 1	0.79^{a}	0.66^{b}	0.73^{a}	0.55^{a}	1.26^{a}	1.18^{b}	1.22^{a}	0.89^{a}
		L 2	0.63^{c}	0.43^{e}	0.53^{c}		0.98^{c}	0.83^{d}	0.91^{b}	
		L 3	0.44^{e}	0.34^{f}	0.39^{d}		0.62^{f}	0.45^{h}	0.54^{e}	
		Mean	0.62^{a}	0.48^{b}			0.95^{a}	0.82^{b}		
	C1	L 1	0.78^{a}	0.49^{d}	0.64^{b}	0.35^{b}	1.00^{c}	0.73^{e}	0.86^{c}	0.72^{b}
		L 2	0.29^{g}	0.18^{i}	0.24^{e}		0.70^{e}	0.55^{g}	0.63^{d}	
		L 3	0.23^{h}	0.11^{j}	0.17^{f}		0.73^{e}	0.58^{fg}	0.65^{d}	
		Mean	0.43^{c}	0.26^{d}			0.81^{b}	0.62^{c}		
	Mean	F.S.	0.53^{a}	0.37^{b}			0.88^{a}	0.72^{b}		
		F.L.	0.68^{a}	0.383^{b}	0.280^{c}		1.0425^{a}	0.7658^{b}	0.5975^{c}	
S 3	C0	L 1	0.65^{ab}	0.63^{b}	0.64^{b}	0.45^{a}	0.95 ab	0.96 a	0.96 a	0.854^{a}
		L 2	0.41^{d}	0.39^{de}	0.40^{c}		0.94^{ab}	0.90^{b}	0.92^{a}	
		L 3	0.23^{h}	0.37^{e}	0.30^{e}		0.75^{d}	0.62^{e}	0.68^{d}	
		mean	0.43^{b}	0.46^{a}			0.88^{a}	0.83^{b}		
	C1	L 1	0.67^{a}	0.34^{f}	0.50^{b}	0.33^{b}	0.93^{ab}	0.60^{e}	0.77^{c}	0.74^{b}
		L 2	0.46^{c}	0.27^{g}	0.37^{d}		0.94^{ab}	0.74^{d}	0.84^{b}	
		L 3	0.12^{i}	0.14^{i}	0.13^{f}		0.81^{c}	0.39^{f}	0.60^{e}	
		mean	0.42^{b}	0.25^{c}			0.89^{a}	0.58^{c}		
	Mean	F.S	0.42^{a}	0.36^{b}			0.89^{a}	0.70^{b}		
		F.L.	0.57^{a}	0.38^{b}	0.22^{c}		0.86^{a}	0.88^{b}	0.64^{c}	

C$_o$ = without compost application, C$_1$= with compost application, SSP= single super phosphate, RP= Rock phosphate, C.T. = Compost treatment, F.L. = Fertilizer level .

Addition of organic amendments to soils increases the immobilization of metals thought adsorption reactions. The organic amendment induced retention of metals is attributed to an increase in surface charge and the presence of metal binding compounds (Clark *et al*., 2007, Gondar and Bernal 2009, Farrel *et al*., 2010, Liu *et al*. 2009, Herwijnen *et al*. 2007 and Zhang *et al*., 2013).

Higher Cadmium accumulation in root of maize plant than shoot can be due to connecting of Cd in cation exchange sites of roots (Zeng *et al*., 2011) and creating complexes with ligands containing –S group (Sulfhydryl) (Topcuoglu, 2012) which led to sediment and accumulation of Cd in apoplast of root.

For the three soils used in this study, generally, it was noticed that, shoots and roots Cd content of plants supplied with RP was significantly lower than plants supplied with SSP. Results in this study showed that single super phosphate was less effective in reducing Cd bioavailability and plant uptake of cadmium than natural rock phosphate. This could probably be due to a slight soil pH reduction after the application of SSP (Zhu *et al*., 2004).

Irrespective of compost treatments and phosphate sources, increasing phosphate levels significantly decreased shoots and roots Cd content (*Zhao et al.*.,2014). Guo, *et al*., (2018) reported that P amendments help to reduce Cd phytotoxicity to crop plants by limiting its availability in the soil through the formation of mixed metal phosphates , which could have restricted Cd uptake by plants.

As for the interaction effect between compost and phosphate sources, in S1, S2 and S3 soils, shoots and roots Cd content of plants grown in soils amended with RP was significantly lower than that amended with SSP for both compost treatments. Concerning the interaction effect of compost application and phosphate levels, data in table (4) revealed that, in all soils studied, increasing phosphate levels significantly decreased shoot Cd content of both compost treatments.

As regards to the interaction effect of compost, phosphate sources and levels, the data in Table 4 show that, for all soils studied, plants grown in soil amended with compost and supplied with RP at high phosphate level recorded the lowest shoot Cd content. It is clear that, applied organic amendments like compost or inorganic additives like RP and SSP were found to reduce toxicity of metals by reducing available fractions, which in turn reduce heavy metal transfer to plants, as indicated by greater plant growth and lower metal concentration in plant (Chen *et al*., 2007).

Shoots and roots lead content of maize plants

The present data in Table 5 show that, the addition of all the applied materials reduced the content of Pb in shoots and roots of maize plants. It was noticed that in all soils studied (S1,S2 and S3), regardless of phosphate treatments, Pb content of shoots and roots were significantly decreased as a result of compost application compared to without application treatment. The percent of decrease in Pb content of shoots were 50, 39.3, 43.4% for S1, S2 and S3, respectively, the corresponding of roots were 9.7, 51.4, 6.1% for S1, S2 and S3, respectively. The obtained results in accordance with the finding of (Angelova *et al*., 2010 and Abo-El-Enein *et al*.,2017). It can be concluded that the toxicity of heavy metals does not depend only on its concentration in soil, but also depends on different forms in which metals are present. The applied compost have high effects on decreasing chemically available Pb in soil as well as decreasing its content in shoots and roots of maize plants (Abo-El-Enein *et al*.,2017)

Table 5. Shoots & roots lead content of maize plants as affected by compost and phosphate Fertilizer applications (mg kg^{-1})

	C.T.	F.L.	Shoots				Roots			
			Fertilizer sources (F.S)			C. Mean	Fertilizer sources (F.S.)			C. Mean
			SSP	RP	mean		SSP	RP	mean	
S 1	C_0	L 1	0.52^{b}	0.5^{c}	0.51^{a}	0.40^{a}	0.85^{a}	0.58^{de}	0.717^{b}	0.683^{a}
		L 2	0.54^{a}	0.26^{e}	0.4^{b}		0.88^{a}	0.56^{de}	0.72^{b}	
		L 3	0.41^{d}	0.19^{g}	0.3^{c}		0.75^{b}	0.48^{g}	0.62^{c}	
		Mean	0.49^{a}	0.32^{b}			0.83^{a}	0.54^{d}		
	C_1	L 1	0.21^{f}	0.22^{f}	0.22^{e}	0.20^{b}	0.85^{a}	0.67^{c}	0.76^{a}	0.617^{b}
		L 2	0.27^{e}	0.19^{g}	0.23^{d}		0.61^{d}	0.54^{ef}	0.57^{d}	
		L 3	0.14^{h}	0.15^{h}	0.145^{f}		0.53^{ef}	0.5^{fg}	0.52^{e}	
		Mean	0.21^{c}	0.19^{d}			0.66^{b}	0.57^{c}		
	Mean	F.S.	0.35^{a}	0.25^{b}			0.75^{a}	0.56^{b}		
		F.L.	0.36^{a}	0.32^{b}	0.22^{c}		0.739^{a}	0.648^{b}	0.568^{c}	
S 2	C_0	L 1	0.69^{a}	0.51^{c}	0.6^{a}	0.61^{a}	1.21^{b}	1.08^{c}	1.15^{a}	1.07^{a}
		L 2	0.63^{b}	0.67^{a}	0.65^{a}		1.29^{a}	1.02^{d}	1.16^{a}	
		L 3	0.53^{c}	0.63^{b}	0.58^{b}		1.12^{c}	0.71^{e}	0.92^{b}	
		Mean	0.62^{a}	0.60^{a}			1.21^{a}	0.94^{b}		
	C_1	L 1	0.43^{d}	0.46^{d}	0.45^{c}	0.37^{b}	0.63^{f}	0.63^{f}	0.63^{c}	0.52^{b}
		L 2	0.58^{ab}	0.26^{e}	0.42^{c}		0.47^{g}	0.47^{g}	0.47^{d}	
		L 3	0.24^{e}	0.26^{e}	0.25^{d}		0.45^{g}	0.45^{g}	0.45^{d}	
		Mean	0.42^{b}	0.33			0.52^{c}	0.52^{c}		
	Mean	F.S.	0.48^{a}	0.47			0.86^{a}	0.73^{b}		
		F.L.	0.52^{a}	0.54^{a}	0.42^{b}		0.886^{a}	0.813^{b}	0.681^{c}	
S 3	C_0	L 1	0.91^{a}	0.83^{b}	0.87^{a}	0.76^{a}	1.05^{a}	0.94^{c}	0.99^{a}	0.822^{a}
		L 2	0.72^{cd}	0.71^{d}	0.72^{c}		0.97^{bc}	0.78^{e}	0.88^{b}	
		L 3	0.61^{e}	0.76^{c}	0.69^{d}		0.61^{f}	0.58^{f}	0.59^{d}	
		mean	0.75^{a}	0.77^{a}			0.88^{b}	0.77^{c}		
	C_1	L 1	0.83^{b}	0.72^{d}	0.78^{b}	0.43^{b}	1.02^{ab}	0.8^{de}	0.91^{b}	0.772^{b}
		L 2	0.48^{f}	0.21^{h}	0.35^{e}		0.98^{bc}	0.59^{f}	0.785^{c}	
		L 3	0.1^{i}	0.25^{g}	0.18^{f}		0.85^{d}	0.39^{g}	0.620^{d}	
		mean	0.47^{b}	0.39^{c}			0.95^{a}	0.59^{d}		
	Mean	F.S.	0.61^{a}	0.58^{b}			0.91^{a}	0.68^{b}		
		F.L.	0.82^{a}	0.53^{b}	0.43^{c}		0.952^{a}	0.832^{b}	0.609^{c}	

C_o = without compost application, C_1= with compost application, SSP= single super phosphate, RP= Rock phosphate, C.T. = Compost treatment, F.L. = Fertilizer level .

In general, it was noticed that regardless of compost treatments and phosphate levels, for the three soils used in this study, shoots and roots Pb content of plants supplied with RP was significantly lower than plants supplied with SSP. These results are in agreement with those found by Zhu *et al*. (2004). The possible mechanisms of RP stabilizing Pb was suggested as a process including ion exchange processes at the surface of RP, surface complexation, and replacement of Ca in RP by Pb with formation of pyromorphite-type minerals (Cao *et al*. 2004), which is very stable even at low pH.

The formation of pyromorphite significantly reduces the mobility of Pb in the soil , transformed from available to unavailable state (residual) it becomes inactive, stable and unavailable for plant uptake (Zhu *et al*., 2004; Cao *et al*., 2009 and Abo-El-Enein *et al*.,2017).

Irrespective of compost treatments and phosphate sources, increasing phosphate levels significantly decreased shoots and roots Pb content. The obtained results are in accordance with the results of Zhu *et al*. (2004) they reported that the pb concentrations in both shoots and roots of two vegetable plants decreased with increasing quantities of added P compound. Guo, *et al*. (2018) reported that plant-tissue concentration of Pb was consistently reduced in the presence of phosphorus, possibly through the formation of mixed metal phosphates , which could have restricted Pb uptake by plants.

Concerning to the interaction effect of compost, phosphate sources and levels, the data showed that, for all soils studied, plants grown in soil amended with compost and supplied with RP at high phosphate level recorded the lowest shoots and roots Pb content.

Available cadmium and Lead in soil after the harvest of maize plants :

The concentrations of available Cd and Pb of the studied soils are shown in Table 6, the results showed that, irrespective of phosphate sources and levels, application of compost significantly decreased the concentrations of available Cd and Pb in all soils studied (S1,S2 and S3). The percent decrease of Cd concentration were; 20 ,60 and 11% for S1,S2 and S3, respectively, the corresponding values for Pb were; 6.4, 5.4 and 15.7% . The results in this study demonstrated that addition of organic amendments caused immobilization of Cd and Pb in the rhizosphere soil. This results are in accordance with Abo-El-Enein *et al*. (2017) they reported that amendment of contaminated soil with organic matter reduced bioavailability of Cd and Pb in the rhizosphere soil.

Table 6. Available cadmium and lead in soil as affected by compost and phosphate fertilizers application (mgkg^{-1})

			Cadmium				**Lead**			
	C.T.	**F.L.**	**Fertilizer sources (F.S)**			**C. Mean**	**Fertilizer sources (F.S.)**			**C. Mean**
			SSP	**RP**	**mean**		**SSP**	**RP**	**mean**	
S 1	C_0	L 1	0.077^{a}	0.071^{b}	0.074^{a}	0.0597^{a}	9.291^{a}	7.94^{abcd}	8.617^{a}	8.213^{a}
		L 2	0.065^{c}	0.050^{e}	0.058^{b}		9.608^{a}	7.62^{abcd}	8.616^{a}	
		L 3	0.051^{e}	0.044^{fg}	0.048 c		9.727^{a}	5.08^{d}	7.402^{ab}	
		Mean	0.064^{a}	0.055^{b}			9.54^{a}	6.88^{b}		
	C_1	L 1	0.059^{d}	0.051^{e}	0.055 b	0.0475^{b}	9.44^{a}	8.69^{abc}	9.06^{a}	7.685^{b}
		L 2	0.047^{ef}	0.045^{fg}	0.046^{c}		9.02^{a}	7.84^{abcd}	8.43^{a}	
		L 3	0.041^{g}	0.042^{g}	0.042^{d}		5.48^{cd}	5.65^{bcd}	5.56^{b}	
		Mean	0.049^{c}	0.046^{d}			7.98^{ab}	7.39^{b}		
	Mean	F.S.	0.057^{a}	0.051^{b}			8.76^{a}	7.14^{b}		
		F.L.	0.065^{a}	0.052^{b}	0.045^{c}		8.84^{a}	8.52^{a}	6.48^{b}	
S 2	C_0	L 1	0.165^{a}	0.151^{b}	0.158^{a}	0.124^{a}	16.87^{a}	12.95^{ab}	14.909^{a}	11.985^{a}
		L 2	0.117^{c}	0.111^{c}	0.114^{b}		10.89^{bc}	12.92^{ab}	11.900^{abc}	
		L 3	0.101^{d}	0.097^{d}	0.099^{c}		10.60^{bc}	7.67^{c}	9.138^{c}	
		Mean	0.128^{a}	0.119^{b}			12.79^{a}	11.18^{a}		
	C_1	L 1	0.065^{e}	0.046^{gh}	0.056^{d}	0.0495^{b}	13.29^{ab}	13.66^{ab}	13.47^{ab}	11.333^{a}
		L 2	0.056^{ef}	0.043^{gh}	0.049^{de}		10.57^{bc}	12.51^{b}	11.54^{bc}	
		L 3	0.050^{fg}	0.037^{h}	0.044^{e}		10.29^{bc}	7.69^{c}	8.99^{c}	
		Mean	0.057^{c}	0.042^{d}			11.52^{a}	11.28^{a}		
	Mean	F.S.	0.092^{a}	0.081^{b}			12.16^{a}	11.23^{a}		
		F.L.	0.107^{a}	0.082^{b}	0.071^{c}		14.19^{a}	11.72^{b}	9.06^{c}	
S 3	C_0	L 1	0.109^{a}	0.098^{b}	0.104^{a}	0.0777^{a}	33.33^{a}	27.46^{b}	30.39^{a}	26.969^{a}
		L 2	0.088^{c}	0.059^{e}	0.074^{c}		29.52^{b}	23.03^{d}	26.28^{b}	
		L 3	0.070^{d}	0.042^{g}	0.056^{d}		28.63^{b}	19.86^{e}	24.24^{bc}	
		mean	0.089^{a}	0.066^{d}			30.49^{a}	23.4^{c}		
	C_1	L 1	0.100^{b}	0.06^{e}	0.081^{b}	0.0690^{b}	28.18^{b}	21.03^{de}	24.60^{bc}	22.730^{b}
		L 2	0.091^{c}	0.053^{f}	0.072^{c}		26.48^{bc}	19.30^{e}	22.89^{ed}	
		L 3	0.072^{d}	0.036^{h}	0.054^{d}		23.73^{cd}	17.96^{e}	20.84^{d}	
		mean	0.088^{a}	0.050^{c}			26.13^{b}	19.43^{d}		
	Mean	F.S.	0.088^{a}	0.058^{b}			28.31^{a}	21.43^{b}		
		F.L.	0.092^{a}	0.073^{b}	0.055^{c}		27.49^{a}	24.58^{b}	22.54^{c}	

C_o = without compost application, C_1= with compost application, SSP= single super phosphate, RP= Rock phosphate, C.T. = Compost treatment, F.L. = Fertilizer level .

Generally, in all studied soils regardless of compost treatments, the results demonstrated that a comparison between SSP and RP revealed that, RP was more effective than SSP because the available Cd and Pb concentrations in RP-treated soils was lower than that in SSP-treated soils , these results are in agreement with Zhu *et al*.(2004) they reported that , the ineffectiveness of SSP in remediating Pb-contaminated soil may probably be due to pH reduction induced by its application in this alkaline soil , they reported the application of hydroxyapatite (HA) increased soil pH by around 0.4 units; the application of rock phosphate (PR) had little effect on soil pH. application of rock phosphate (PR) had little effect on soil pH. Unlike HA and PR, the application of single super phosphate (SPP) decreased soil pH by about 0.9 unit. Chen *et al*. (2007) reported the soils pH increased due to the addition of RP. This may be due to much $CaCO_3$ contents in RP which makes it as alkaline characteristic. On the contrary, the application of soluble P amendments such as triple super phosphate (TSP), single super phosphate (SSP) and diammonium phosphate (DAP) was reported to decrease soil pH (Chen *et al*., 2007).

Also, the data show that increasing phosphate levels significantly decreased available Cd and Pb in the three soils used. Zhu *et al.* (2004), reported that concentration of available Pb decreased with increasing quantities of P amendments . Various mechanisms have been advanced to explain the immobilization of Cd and Pb by phosphate amendments. A dissolution- precipitation mechanism via the formation of pyromorphite-like mineral was used to explain the decrease in pb availability in previous studies (Chen *et al.* 2007; Debela *et al.* 2013). Da Rocha *et al.* (2002) suggested that Cd immobilization could be associated with the ion exchange and complexion mechanisms. Surface adsorption or fixation mechanisms involving the formation of Cd-phosphate on the surface of the amendment were also reported in several studies (Marchat *et al.* 2007; Matusik *et al.* 2008 ; Mignardi *et al.* 2012).

Concerning the interaction effect of compost treatments and phosphate levels , data in Table 6 reveal that, in all soils studied, increasing phosphate levels significantly decreased available Cd and Pb in soil in both compost treatments. The data show that, for all studied soils, soil amended with compost and supplied with RP at high level recorded the lowest available Cd and Pb.

CONCLUSION

This pot experiment demonstrated that the application of soil amendments used in this study, a compost as organic amendment , natural rock phosphate (RP) and single supper phosphate(SSP) to contaminated soil decreased the Cd and Pb availability in the soils, which in turn promoted plant growth, and thus decreased the Cd and Pb accumulation in maize plants. Amendments of compost with RP were the most effective in reducing Cd and Pb availability, so the application of such materials can be used as effective strategy to remediate soils polluted with Cd and Pb.

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تأثير إضافة الكمبوست والفوسفات على نمو وامتصاص الكادميوم والرصاص بواسطة نباتات الذرة النامية في الأراضي الملوثه

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أقيمت تجربة أصص باستخدام الذرة الشامية (هجين فردي- ٢٠٣٠) لدراسة تأثير مصادر ومستويات الفوسفور وإضافة الكمبوست على نمو نبات الذرة ومحتواه من عنصري الكادميوم والرصاص وكذلك دراسة صلاحية كلا من عنصري الكادميوم والرصاص في حيز نمو الجذور بعد حصاد نباتات الذرة وذلك باستخدام ثلاث أنواع من الأراضي الملوثة. وقد لوحظ في كل عينات التربة المستخدمة في الدراسة أن إضافة الكمبوست أدت إلى زيادة معنوية في الوزن الجاف لكل من الأجزاء الخضرية والجذور لنباتات الذرة وكان تأثير إضافة الكمبوست أكثر وضوحاً من إضافة الفوسفات. دلت نتائج التجربة على أنه باستخدام عينات الأراضي الثلاث المستخدمة، فإن النباتات التي نُميت في الأراضي التي عوُملت بالكمبوست وأمدت بصخر الفوسفات بالمعدل العالي سجلت أعلى وزن جاف لكل من الأجزاء الخضرية والجذور. أدت إضافة الكمبوست إلى نقص معنوي في محتوى الأجزاء الخضرية والجذور لنباتات الذرة من عنصري الكادميوم والرصاص ، كذلك أدت إضافة صخر الفوسفات إلى نقص معنوي في محتوى الأجزاء الخضرية والجذور من عنصري الكادميوم والرصاص بالمقارنة بإضافة سوبر فوسفات الكالسيوم وذلك في كل الأراضي المستخدمة في الدراسة، ومن ناحية أخرى فقد أدت زيادة معدلات الفوسفات إلى نقص معنوي في محتوى الأجزاء الخضرية والجذور من عنصري الكادميوم والرصاص في عينات الأراضي الثلاث المستخدمة. كذلك اظهرت النتائج أن النباتات التي نُميت في الأرض التي عوُملت بالكمبوست وأمدت بضخر الفوسفات بالمعدل العالي سجلت أقل محتوى من عنصري الكادميوم والرصاص في كلا من الاجزاء الخضرية والجذور وذلك مع كل الاراضي تحت الدراسة. أدت إضافة الكمبوست إلى الأراضي محل الدراسة إلى نقص معنوي في الكادميوم والرصاص الميسر في حيز نمو الجذور وذلك بعد حصاد نباتات الذرة ومن ناحية أخرى فقد أدت إضافة صخر الفوسفات إلى الأراضي محل الدراسة إلى نقص معنوي في الكادميوم والرصاص الميسر في حيز نمو الجذور بالمقارنة بإضافة سوبر فوسفات الكالسيوم، كذلك فقد أدت زيادة معدلات إضافة الفوسفات إلى نقص معنوي في الكادميوم والرصاص الميسر في حيز نمو الجذور في عينات الأراضي الثلاث المستخدمة. سجلت معاملة اضافة الكمبوست مع اضافة صخر الفوسفات بالمعدل العالي اقل تيسر لكلا من عنصري الكادميوم والرصاص في حيز نمو الجذور.